SPECIFICATION

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600 A and 120 A Vapor Cooled Current Lead Assemblies for the LHC Interaction Region Feedboxes (DFBX)

1. Scope

This specification is for the design, manufacture, test, and delivery of vapor cooled lead assemblies needed to supply 600 A and 120 A DC to superconducting accelerator magnets. The superconducting magnets are part of the interaction regions that will be used at CERN in Geneva, Switzerland for the Large Hadron Collider (LHC). The hardware delivered to CERN is provided by the US-LHC Accelerator Project, which is funded by the US DOE.

The vapor cooled current lead assemblies (referred to as feedthroughs) will be installed in eight cryogenic feedboxes, designated by CERN as DFBX. The DFBX Functional Specification is found in CERN document LHC-DFBX-ES-100.00 rev 1.0. After testing, the completed DFBX will be shipped to CERN for installation in the LHC.

In order to minimize the heat load on the cryogenic system and thereby decrease both capital and operational costs associated with the refrigeration plant, we are requiring that the feedthroughs be cooled by helium vapor.

2. Reference Documents

The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the document used shall be the one in effect on the date of request for quotation. Any conflicts between this specification and the referenced documents shall be brought to the attention of LBNL in writing for resolution before any related action by the seller.

2.1 LBNL Documents

LBNL DRAWINGS:
24C352; Feedbox Assembly
24C353; 600 Amp, 6 Lead Assembly
25I164; 600 Amp 2 Lead Assembly
24C322; 120 Amp Lead Assembly
24C353; SHEET 2; 600 Amp Lead
24C322; SHEET 2; 120 Amp Lead
25I619; DFBXG Wiring Diagram

LBNL PROCEDURES:
600 A Lead Splice Procedure, LBNL Note: M982
120 A Lead Splice Procedure, LBNL Note: M983

2.2 CERN Documents

LHC-DFBX-ES-100.00 rev 1.0, "Functional Specification for Inner Triplet Feedboxes, DFBX"(prepared by LBNL)
LHC-PM-ES-0002.00 rev 1.0, General Parameters for Equipment Installed in the LHC".
LHC-PM-QA-206.00, rev 1.1, "LHC Part Identification".
LHC-PM-QA-309.00 rev 1.0, "Manufacturing and Inspection of Equipment".

3. Requirements

3.1 General Configuration

The current feedthroughs will be arranged in three types of clusters that are installed in the DFBX per LBNL Drawing 24C352. The three types of clusters are (1) three pairs of 600 A leads as shown on LBNL drawing 24C353, (2) one pair of 600 A leads as shown on LBNL drawing 25I164, and (3) five pairs of 120 A leads as shown on LBNL drawing 24C322. The clusters are installed in individual chimneys arranged in a row and angled at 10° from vertical on the top of the feedbox. Each feed box requires the following set of lead clusters:

- Two each of type one, three pairs of 600 A leads
- One each of type two, one pair of 600 A leads
- One of type three, five pairs of 120 A leads

3.2 Current Rating

The continuous current capacity shall be 600 for the Type 1 and Type 2 leads, and 120 A for the Type 3 leads. They shall withstand the maximum current with no coolant gas flow for 60 seconds, without causing any degradation of the lead performance as measured by electrical resistance and coolant gas flow.

3.3 Voltage Rating

The lead shall withstand a test voltage of 600V dc to ground with the lead in a helium gas environment of 1.3 bar and temperature between 4.5 K and 300 K, and 2000 V in air at atmospheric pressure and room temperature. The leakage current after 1 minute at 600V at normal standby conditions (1.3 bar helium gas, 0 current, 4.5 K cold end temperature) shall be less than 5 microamps.

3.4 Heat Load to 4.5 K Bath (Operational) for Type 1 leads

The total heat load to the 4.5 K helium bath shall be less than 0.7 W per lead at 600 A.

3.5 Heat Load to 4.5 K Bath (Operational) for Type 2 leads

The total heat load to the 4.5 K helium bath shall be less than 0.14 W per lead at 120 A.

3.6 Heat Load to 4.5 K Bath (Standby) for Type 1 leads

The total heat load to the 4.5 K helium bath shall be less than 0.5 W per lead.

3.7 Heat Load to 4.5 K Bath (Standby) for Type 2 leads

The total heat load to the 4.5 K helium bath shall be less than 0.09 W per lead.

3.8 Warm Terminal Temperature

The temperature of the warm terminal shall be maintained at greater than 20 C (8 C above the design dew point in the LHC tunnel), in order to prevent moisture condensation. This will require the installation of heaters on the lead upper end. The heaters shall have separate leads for power and control. The heater power source shall be 24 V ac.

3.9 Design Pressure

The current lead cluster shall be designed to withstand a test pressure of 4.4 bar absolute applied to the current lead chimney.

3.10 Leak Rate

Vendor shall verify that the leak rate to atmosphere is less than 1 x 10^{-8} std. cc/sec (helium) for each current lead assembly. The test can be performed with vacuum on the lower end and helium gas applied to the warm end.

3.11 Operational Requirements

The desired operational lifetime of the current lead is 15 years at full current, which includes a minimum of 30 thermal cycles between room and operating temperatures and a minimum of 3000 electrical cycles between zero and full operating current. The vendor shall specify the gas flow rates under operating and standby conditions, the lead voltage drops expected in normal operation, and the maximum allowable lead voltage drops.

3.12 Instrumentation

Each lead shall contain temperature sensors, voltage taps, and heaters for process control and protection.

3.12.1 Temperature Sensors

One temperature sensor on each lead is required to measure the warm terminal temperature. A suggested location for the temperature sensor is shown on Drawing 24C353 sheet 2 for type 1 and Drawing 24C322 sheet 2 for type 2. Redundancy is provided since only one thermometer per pair is needed for heater control.
The temperature sensors and lead wires shall be insulated to satisfy the voltage rating in Section 3.3. During the testing in Section 3.3 the temperature sensors and their lead wires shall be at ground potential. The temperature sensor lead wire shall be terminated in a kapton-insulated cable extending 3 m from the assembly.

3.12.2 Voltage Taps

The Vendor shall attach voltage taps at the locations shown on Drawings 24C353 and 25I164 for the 600 A leads and Drawing 24C322 for the 120 A leads. In addition, each lead shall be provided with a voltage tap wire that will be attached to the bus bar in the DFBX by others. The voltage wires shall satisfy the voltage rating in section 3.

3.12.3 Signal Feedthroughs

The voltage tap feedthroughs shall be Douglas Electrical No. 14513 or equivalent. The location of the feedthrough is shown on Drawing 24C353 and 25I164 for the 600 A leads and Drawing 24C322 for the 120 A leads. The Vendor shall ensure sufficient thermal isolation from the cold sections of the lead to prevent condensation or ice formation on the wires. The feedthroughs shall be wired as shown on LBNL drawing 25I615.

3.12.4 Heater Connections

The heater power leads shall be terminated in a Kapton-insulated cable extending 3 m from the current lead assembly.

3.13 Physical Constraints

3.13.1 Overall Length

The overall length of the lead, measured from the bottom of the cold terminal to the top of the GHe outlet port, shall be as shown on drawing 24C353 sheet 2 for the 600 A leads and drawing 24C322 sheet 2 for the 120 A leads.

3.13.2 GHe Outlet Port

The GHe outlet port for the 600 A leads shall be a Conflat™-type flange, non-rotatable, 1 1/3 inch (34 mm) diameter, with clearance holes for the mounting bolts. The Vendor shall provide metric stainless steel fasteners. The Ghe outlet port for the 120 A leads shall be a Cajon male VCR (Size 4) fitting.

3.13.3 Lug Terminal

The current terminal shall be fabricated from OFHC copper and exposed surfaces plated with a suitable material such as silver, tin, or nickel to prevent oxidation of the connection surfaces. The dimensions of the terminal are shown on Drawing 24C353 sheet 2 for 600 A leads and Drawing 24C322 sheet 2 for 120 A leads.

3.13.4 Room Temperature Mounting Flange

The room temperature mounting flange shall be a Conflat™ -type, non-rotatable, 8-inch (203.2-mm) diameter, with clearance holes for the mounting bolts. The Vendor shall provide metric stainless steel fasteners.

The room temperature mounting flange is at ground potential, when the leads satisfy the voltage requirements of section 3.3.

3.13.5 Length of Lead Inside the DFBX

The bottom end of the cold terminal shall be located 39.1 inches below the room temperature mounting flange in 3.13.4.

3.13.6 Lead Outer Diameter

The maximum outer diameter of the lead array, including electrical insulation, below the structural ring shall be less than 4.99 inches for the 120 A lead assembly and 5.01 inches for the 600 A lead assembly.

3.13.7 Connection to Nb-Ti and Copper Cables

The cold connections shall be made per the splicing procedures in Attachments A and B. Vendor shall ensure that internal current lead solder joints be clamped to prevent their degradation during customer splicing. The cold terminal shall have sufficient area immersed in liquid helium to avoid film boiling under all working conditions.

3.14 Lead Installation and Removal

To facilitate installation and removal of the Lead into the DFBX, vendor shall provide lifting points.

3.15 Heater

The Current Lead shall be equipped with an electric heater to prevent condensation and frost from forming on the room temperature sections of the Current Lead when the Lead is in standby (zero current) or when operated at reduced currents. Electrical insulation between Heater and Current Lead to satisfy section 3.3 shall be provided. The space between the heater cartridge and the lead shall be filled with a high thermal conductivity compound in order to provide good heat transfer. The maximum temperature of the heating element shall be 150 C, and the temperature difference between the block and heating element shall be 1 C. The warm terminal shall be constructed of materials that can withstand the low temperatures that would result from a failure of the heating system, and remain leak tight.

3.16 Transportation

The completed DFBX will be shipped to CERN following final installation of the current leads and cryogenic piping. Lead assemblies should withstand at least 1.1 G in all directions during DFBX shipment to CERN

4. Materials of Construction

4.1 Resistive Section

Conventional resistive current lead materials such as copper, stainless steel, brass, Ag braze, and Pb-Sn solder shall be used to fabricate the resistive section of the lead.

4.2 Insulation Materials

Insulation materials that are suitable for use in the current leads include Kapton, Vespel, PEEK, G-10CR, and G-11CR. Teflon shall not be used.

5. Marking

The following information shall be stamped on the mounting flange edge of each lead assembly in block letters at least ¼ inch (6.4 mm) high. See drawings 24C353, 25I164 and 24C322 for the desired location. Space shall be provided around each individual lead for a ½ inch high, two digit numeral to be stamped on the face at a later time.

Lead Current Rating (A)
LBNL Specification Number
Vendor Name
Vendor Serial Number
Date of Manufacture
Country of Manufacture

6. Quality Assurance

6.1 General

Vendor shall have and utilize a general, company-wide quality assurance plan adapted as required for the LHC Current Lead Project. The Plan shall address design, material procurement, fabrication, process control, process-testing, and final testing.

6.2 Hold point for LBNL approval of design

After the detailed design is complete, the design package shall be sent to LBNL for review and approval before the vendor proceeds with fabrication.

6.3 Vendor Inspection and Testing

The Vendor is responsible for carrying out the inspection and testing required by the Quality Plan in 6.1. LBNL technical representatives reserve the right to witness critical inspections and tests at the Vendor or Subcontractor facilities. As a minimum, Vendor shall perform

(1) Dimensional checks of the completed assembly
(2) Full-current tests to verify the requirements in 3.2 (may be done on individual pairs before assembling, using the splice procedures in the appendix).

(3) Zero current, full flow tests to verify 3.8.
(4) Hipot testing in completed assembly to verify 3.3. A test chamber will be required.
(5) Pressure testing to verify 3.9.
(6) Leak testing to verify 3.10.

6.4 **Vendor Deliverables**

1. Design package including design data and drawings prior to start of production
2. A total of 32 units are required, broken down by type and listed below:

No. of units	Type
16	3-pair 600 A cluster, per Drawing 24C353
8	1-pair 600 A, per Drawing 25I164
8	5-pair 120 A cluster, per Drawing 24C322

3. Inspection and test reports specified in Section 6.2.
4. Final design package, including as built drawings.

6.5 Testing at LBNL

LBNL intends to test all or a portion of the feedthroughs purchased under this Specification for compliance. Testing results will be made available to the Vendor. In the event that substandard performance is measured in this testing, the Vendor will be required to make the necessary repairs or provide replacement articles to meet the requirements of this Specification.

7. Shipment

The Vendor shall package the vapor cooled current lead assemblies for shipment in a sufficiently rugged shipping container. The assemblies shall be wrapped in a weather-tight plastic film to prevent moisture and other contaminants from degrading the performance. The assemblies shall be mounted in the rugged container with shock absorbing mountings or packaging to prevent damage due to shipping loads.

The test and inspection reports (travelers) required in Section 6.3 shall be shipped with each feedthrough. The Vendor Serial number shall appear on the reports to allow correlation of traveler to the corresponding lead.

The container shall be clearly marked with the serial number of the feedthroughs (s) contained within